6

Design and Construction

Contents

Supplement

*** Revised March 1997. Please note that no changes were made to the other sections.**

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Design and Construction

6.01 Introduction

All LLNL equipment and facilities must be designed and constructed to provide the safest work environment possible, within acceptable economic and operational limitations. If adequate controls are included in the engineering designs, the risks associated with most, if not all, credible hazards can be reduced to an acceptable level. This particular method of applying controls has been found to be the most efficient and cost effective. However, controls that depend on human activation—personal protective equipment and administrative procedures—should be used only as auxiliary methods for controlling hazards (see Chapter 2).

6.02 Responsibilities

Departments that design, assemble, or construct facilities or equipment shall assign these responsibilities to qualified and competent personnel. The engineering departments are staffed with experienced engineers, technicians, and craftsmen who can perform these functions properly when called on. Make maximum use of their services.

Designers shall follow all prescribed codes and standards, analyze their projects for all credible hazards, and incorporate any reasonable controls that will reduce the risks to an acceptable level. All calculations shall be checked and signed by another qualified person and then retained for the usable life of the item. In addition, provisions of the Quality Assurance Program that are required shall be incorporated in the design and followed during construction (*Manual M-078*). Designers should contact Hazards Control for assistance if any unusual hazards are associated with the operation of either the facility or equipment. Technicians and construction workers shall use approved work practices and produce a quality product that meets design and code requirements.

The LLNL Construction Safety and Health Program shall conform to the requirements of DOE Order 5480.9. These requirements include:

- Safety and Health Program for project construction contractors.
- Safety and Health Program for resident construction contractors.
- Program compliance.
- On-site construction inspections.
- Point of contact.

Details of the LLNL Construction Contractor Safety Program are contained in Supplement 1.11 of the *LLNL Health & Safety Manual*.

6.03 Maintenance and Inspection

Proper maintenance can ensure maximum operating life of equipment at minimum cost and minimum risk to personnel. Designers shall consider the maintenance requirements when designing equipment and facilities.

There are two types of maintenance operations:

- *Daily maintenance* to ensure that the equipment is kept clean and operable and the facilities are in good condition.
- *Preventive maintenance*, which involves the overhaul of equipment and facilities on a predetermined schedule before breakdown occurs.

The program for inspecting equipment and facilities is essential to preserve a low-risk work environment. The inspection process should uncover any areas where the original design, basic construction features, or routine maintenance practices have become less than adequate. When discovered, such conditions shall be promptly corrected. The priority and extent of the correction is directly related to the risk associated with the unacceptable condition.

The Contractor Maintenance and Inspection Program at LLNL shall conform to DOE Order 5480.9.6a(1)(1) and 5480.9.6.d. These requirements include programs for

- Training, inspecting, reporting, and certifying safe operating conditions.
- Assuring proper maintenance of earth-moving equipment, cranes, vehicles, pressure vessels, and protective devices for portable electric tools.

The on-site construction inspections shall include several factors, such as:

- Number and type of hazards involved;

- Total level of risk to the workforce, property, and environment;
- Previous experience with the contractor;
- Presence of qualified contractor safety personnel;
- Duration of the project;
- Time elapsed since the last inspection; and
- Availability of independent sources of inspection.

6.05 Facilities

Facilities shall be designed to meet all applicable codes and standards, as well as the criteria set forth in appropriate chapters of this *Manual*.

These codes and standards include:

- DOE Orders 6430.1A, 5480.4, and 5480.9,
- Life Safety Code NFPA 101, and
- OSHA 1910 and 1926.

Hazards Control will review plans and drawings before construction to ensure they conform to all applicable health and safety codes.

Before any facility is occupied, or any new or significantly modified project begins operations, the responsible Program or Facility management shall conduct an Operational Readiness Review. The formality and rigor of the review will vary according to the complexity and potential hazards involved.

The range may vary from a joint "walk-through" final inspection by representatives of the occupying or operating Program, Plant Engineering, and Hazards Control, to a formal review modeled on the DOE "Occupancy-Use Readiness" Manual. The Program or facility management shall coordinate with the Hazards Control Safety Team Leader to determine the appropriate level-of-readiness review.

Boilers

Heating-system boilers shall conform to current standards of the American Society of Mechanical Engineers (ASME), Underwriters Laboratories (UL), Industrial Risk Insurers (IRI), California Administrative Code (CAC), and Factory Mutual (FM). For specific regulations, refer to the following:

- ASME Boiler and Pressure Vessel Code, Section IV, "Heating Boilers."
- UL 795, "Commercial Industrial Gas Heating Equipment."
- UL 726, "Oil-Fired Boiler Assemblies."
- LLNL Engineering Standards PEL-M-15626.
- Industrial Risk Insurers (formerly FIA), "Recommended Good Practice for Combustion Safeguards on Single-Burner Boilers-Furnaces."
- FM, Loss Prevention Data Sheet 12-37 (low water cutoff).
- CAC, Title 8, Chapter 4, Subchapter 2.
- CAC, Title 24, "Electrical Control."

State permits are required for all high-pressure boilers, stationary and mobile air receivers, LPG storage tanks, and anhydrous ammonia and propane installations. No state permit is required for low-pressure boilers. Plant Engineering is responsible for code compliance, coordinating state inspection, and obtaining state permits.

Carpeting

Carpeting used to cover horizontal floor surfaces shall have a Flame-Spread Index (ASTME 84) no greater than 75.

Elevators

All elevators installed in LLNL buildings shall conform to the *California Administrative Code, Title 8, Subchapter 6*, "Elevator Safety Orders."

Emergency Lighting

An emergency lighting and electrical system supplies light and power if the regular power fails to operate. The system must activate within 10 s of the failure and sustain a minimum 1 ft-candle illumination at floor level for a period of 1-1/2 hr. Emergency lights must be installed in all regularly used or occupied areas where a power outage will make exiting the area difficult or dangerous. An emergency-lighting system must be designed to meet Engineering Standards PEL-E-10 or PEL-E-12.

Eye Washes and Emergency Showers

Protecting the skin and eyes from exposures to hazardous materials requires good planning, proper personal protection, and effective supervision and training. However, since accidents can still occur, safety showers and eye-wash stations shall be installed in laboratories, shops, flammable-liquid-dispensing areas, battery-charging rooms, photolabs, and all indoor and outdoor areas where significant amounts of corrosive, flammable, or other hazardous materials are regularly used.

Safety showers and eye washes are required, but are not limited to:

- Areas where the following chemicals are used:
  - — Inorganic and organic acids (see Supplement 21.15, "Safe Handling of Acids and Bases").
  - — Solutions of inorganic or organic acids or bases with a pH of less than 2.0 or more than 12.
  - — Other organic or inorganic materials that are corrosive or irritating to the eyes or skin (e.g., methylene chloride, phenol).
  - — Organic or inorganic materials that are significantly toxic by skin absorption (e.g., phenol).

- Areas where the chemicals above are used in a closed system that can catastrophically fail and cause the chemicals to leak (i.e., lead-acid battery-charging areas, or areas where pressurized systems with caustic or other strong irritant liquids are used).
- Storage areas where breakable containers (1 gal or more) are handled outside their original shipping cartons (e.g., glass bottles of corrosive chemicals removed from their original cardboard boxes).
- All chemical storage and handling areas, including waste accumulation areas, that contain the types of materials listed above.
- Areas where dip tank operations are performed and the possibility of a splash exists.
- Areas where operations involve the use of air or water reactive liquids or solids (e.g., $AsC1_3$).

When the chemicals previously listed are used in small quantities (less than 500 ml) and the liklihood of exposure is limited, only an eye wash may be required. When the quantities are larger and significant splashing or spraying may occur, a safety shower shall also be required.

Generally, eye washes are not required in areas where

- The chemicals previously listed are stored in quantities less than 8 ounces and used at room temperatures at a rate of less than 2 ounces per day. (Note: Perchloric acid, hydrofluoric acid, and the alkali metals are exempt from this requirement.)
- Compounds hazardous to the eyes or skin are used in sealed systems at or below atmospheric pressure and tatastrophic failure or leakage is unlikely. However, an eye wash or shower may be appropriate if the system is filled, topped off, or drained in other than a totally enclosed manner.
- Materials hazardous to the eye or skin are stored in bulk in metal or plastic containers and not decanted.

The area ES&H team should be consulted for specific determinations or exceptions.

Equipment. Eye washes and safety showers installed in 1990 or later must comply with the installation requirements in ANSI Z358.1-1990. Those installed earlier than 1990 that do not meet the requirements of ANSI standard requirements should be modified (or replaced) if there is the potential for significant hazards to the eyes or skin during operation.

The preferred equipment is a combination deluge shower and foot-operated eye-wash fountain that fully drenches a contaminated person, but allows free use of the hands to assist opening the eyes while washing them.

Location. Safety showers and eye washes shall be located as closse as possible to the working area, but far enough away from the workstation so that if a major spill or fire occurs the contaminated person can leave the immediate danger area and use the equipment safely. The maximum distance is 100 ft (or 100 s of travel time), but smaller distances may be warranted depending on the nature of the hazard (e.g., large amounts of corrosives in open containers). Before installing a shower, consider the path to the shower with respect to contact with other hazards (open fume hoods, stairs, hot surfaces, closed doors with latches, possibility of eye injury). In addition, make sure that safety showers and eye washes are not located near electrical contacts, for this can be a hazard when the shower is in use.

Installation. Plumbing of safety showers and eye-wash fountains shall be connected to potable water systems. The minimum pressure required is 0.207 MPa (30 psi). The pipe size shall be large enough to supply water, as specified in the manufacturer's installation instructions. Floor drains should be installed near the shower if flooding will create a serious hazard. The location for all plummed eye wash or safety shower must be well lighted and identified with a highly visible sign. Nonplumed (portable) eye washes and safety showers shall not be used unless a plumbed unit is infeasible. If these units must be used, they shall meet the performance and access requirements in ANSI Z358.1-1990 (or latest version). Hand-held eye-wash bottles are not permitted.

Testing, Maintenance, and Training. Area supervisors (or the building or trailer coordinator) are responsible for

- Ensuring all safety showers are inspected quarterly and that eye washes are inspected weekly. Inspections shall include a visual check and activation of the devices and flushing of the water lines (1 minute minimum, 3 minutes recommended). Note that the piping configuration for each system should be taken into consideration when flushing the water lines to ensure that stagnant water is thoroughly flushed out.
- Documenting the test results of all inspections.
- Maintaining all safety showers and eye washes, including portable eye washes, in the area. The water in nonplumbed eye washes should be replaced at least quarterly with clean, potable water (preferrably 140°F or hotter to kill any Acanthamoeba) and a commercial biocide added in accordance with the manufacturer's instructions.
- Training employees in the use of all equipment.

Out of Service Equiipment. Facilities, work areas, or units that are no longer in use or tested shall be posted with an "Out of Service / Untested" sign. These areas and units will be evaluated before they can be activated for operations requiring the use of hazardous chemicals and emergency deluge equipment. Thereafter, the normal testing program shall resume.

Reference.

- *American National Standard for Emergency Eyewash and Shower Equipment*, ANSI Z358.1-1990 (or latest version).

Ventilation Equipment

Ventilation system requirements are described in Chapter 12 of this *Manual*.

Seismic Protection

Seismic protection requirements are described in Chapter 27 of this *Manual*.

Roofing Materials

If a roof is to be tarred, use asphalt tar. Limit the use of coal-tar pitch, a recognized human carcinogen, to patching existing coal-tar-coated roofs.

Site Planning Criteria

Successful emergency operations by the Fire Department depend on a quick and efficient response to the emergency scene. Restricted or blocked building access or improperly located hydrants and sprinkler equipment can reduce the effectiveness of emergency crews. The proper separation of buildings is also important to prevent a fire in one building from creating an external fire hazard to a nearby building.

There are rules to be followed in the siting of new facilities. These criteria shall be considered early in the planning stages for new facilities as well as for facility additions or modifications. The siting rules are based on DOE-mandated codes and standards and on the emergency equipment used by the Fire Department. Hazards Control conducts a design review of plans for all new facilities and additions; however, it is important that for siting issues the Fire Safety Division be consulted in the very early stage of planning so that design efforts are not wasted.

6.06 Environmental and Safety Analysis

The design, construction, management, operation, and maintenance of LLNL facilities, activities, and projects shall be undertaken without undue risk to the safety and health of employees and the public. Sources of pollution shall also be controlled to protect the environment as prescribed by applicable federal, state, and local environmental protection laws. In addition, the Laboratory must:

- Protect government property against accidental loss and damage.
- Assure compliance with applicable statutory requirements.
- Assure quality assurance is pursued.

References

- DOE IMD Appendix 6101, "Management of Construction Projects."
- DOE Order 5481.1B, "Safety Analysis and Review System for DOE Operations."
- DOE Order 5440.1B, "Implementation of the National Environmental Policy Act."
- *Health & Safety Manual*, *Supplement 1.13*, "Safety of Nuclear Facilities."
- *Health & Safety Manual*, *Supplement 6.06*, "Safety Analysis Guide."

6.08 Trailers and Temporary Buildings

Trailers and temporary buildings are of lightweight construction and often fabricated of combustible materials that present a considerable fire and earthquake risk. To increase the safety of these facilities, they shall not be larger than 465 m^2 (5000 ft^2) for structures without sprinklers, 1400 m^2 (15,000 ft^2) for structures with sprinklers, or 93 m^2 (1000 ft^2) for chemical laboratories. Anchors, tiedowns, and supports shall be installed on all trailers according to Plant Engineering standards that meet or exceed the requirements of the Uniform Building Code. For detailed guidelines on protecting these structures from fire, refer to the DOE report, *Standard on Fire Protection for Portable Structures* (DOE/EV-0043, August 1979).

6.09 Laboratories

The general criteria for designing, constructing, and equipping most laboratory rooms include:

- Two unobstructed exits.
- Smooth wall finish.
- Automatic fire-protection system.
- Emergency eye-wash fountains and showers.
- Emergency lights.
- Safe storage areas for chemicals, considering the effects of fire, toxicity of the chemicals, and earthquake.
- Impermeable work surfaces.
- Ventilated enclosures (Chapter 12).
- Operational shields (Section 6.23).
- Warning signals and signs (Chapter 11).
- Safety interlocks for high-energy equipment (Section 6.24).
- Seismic tiedown (Chapter 27).
- Additional criteria for special-use laboratories are found in the references listed below. Contact Hazards Control for more information.
- Radioactive-material workplaces—*Health & Safety Manual Supplement 33.42* and Section 33.42.
- X-ray machines (Section 33.47).
- Accelerators (Section 33.48).

• Explosive-material workplaces—*Health & Safety Manual Section 6.13.*

• Carcinogenic and toxic material work places—*Health & Safety Manual Supplement 21.16.*

6.10 Change Rooms

Change rooms may be required at the entrance to some hazardous-material areas if persons entering the area must wear protective clothing. This section describes an idealized change room; however, specific circumstances may require other arrangements. Change rooms shall be located where they are the only non-emergency entry and exit points for those working in the hazardous-material work area. A change room should consist of sequential modules designed to provide an orderly progression:

- Entrance.
- Protective-clothing-dispensing module.
- Locker module for storing street clothes.
- Work-shoe (or shoe-cover) dispensing module.
- Entry portal to the work area.

When exiting the area, the sequence should be:

- Monitoring module.
- Exit portal from the work area.
- Contaminated-clothing-removal module.
- Shower.
- Monitoring station to check for the presence of radioactive contamination (if applicable).
- Clearly defined step-off line to decontaminate potentially contaminated from uncontaminated areas.
- Original locker to obtain street clothes.
- Exit to the outside area.

6.11 Battery-Charging Rooms

Contact with the strong, highly corrosive acid used in storage batteries can cause severe chemical burns to personnel. This acid can also damage equipment in battery-charging areas. The stored energy in the batteries is a potential electrical-shock hazard. In addition, batteries being charged produce a flammable gas (hydrogen), which can accumulate in confined spaces, creating an explosion hazard. To control these hazards, battery-charging areas shall meet the following requirements:

- Accessible to qualified personnel only. (A locked enclosure is desirable, particularly for large systems.)
- Safety shower and eye wash within 100 ft (or 10 s of travel time).
- Adequate ventilation to remove flammable gas and irritating electrolyte mist.
- No sources of ignition (i.e., flames or sparks) nearby.
- Impermeable, acid-resistant floor that can be kept dry.
- Method of preventing the spread of leaking acid to the environment.
- Battery racks and trays constructed of nonconductive, acid-resistant materials or covered with a nonconductive, acid-resistant coating.
- Battery terminals guarded to prevent dropped tools or other objects from shorting them.
- Wiring methods that meet current National Electric Code requirements.
- "No Smoking" signs posted.
- Warning signs posted specifying the personal protective equipment required to service the batteries.
- Storage facilities in the area to maintain personal protective equipment (i.e., faceshield, gloves, etc.) in clean, usable condition.
- No battery-charging equipment in mechanical equipment rooms. (The exception to this is to require an engineering design review.)

All of these requirements should be met when installing battery-charging systems. Some requirements may be waived if an alternative design provides equal protection. Contact your Hazards Control Safety Team for advice.

6.13 Explosives Laboratories

Work with explosives entails a level of risk dependent on the amount and sensitivity of the explosive involved and the type of operation to be performed. Before the facility is designed, a careful study of these variables must determine the amount of protection to be given the operator. Design criteria for explosive facilities are contained in DOE Order 6430.1A. Chapter 24 of this manual and the *DOE Explosives Safety Manual* (DOE / EV / 06194) describe explosives safety programs and basic controls to implement DOE safety policy for operations involving explosives. The following guidelines are applicable to all laboratory operations:

- Design walls between adjoining rooms to withstand the effects (blasts and fragments) of an accidental detonation. The walls must protect any personnel not directly involved in the operation.
- Whenever blasts could cause laboratory window breakage, use nonshattering plastic instead of glass.
- Provide unobstructed escape routes into less hazardous areas. The number of exits from each room shall be in accordance with the Life Safety Codes NFPA 101 and the *DOE Explosives Safety Manual* (DOE / EV / 06194).

- Provide floor surfaces free of cracks or other places where explosives contamination could accumulate. If liquid explosives are used, seal the floor to prevent absorption of the explosive. Cover all floor drains to prevent spilled explosive from entering the sanitary sewer system.
- In rooms containing remote operations, equip all entrances with physical barricades. These entrances should be interlocked to the equipment involved in the remote test.
- NEC (NFPA 70) approved wiring and equipment shall be used in laboratories unless a hazard analysis is accomplished and revised independently, as prescribed in Chapter II, Section 8 of the *DOE Explosive Safety Manual* (see also *Health & Safety Manual*, Section 24.13 for additional requirements).

6.20 Equipment

Properly designed and assembled equipment plays an important part in determining the achievement of programmatic goals. Much of the equipment used in the experimental areas is unique, requiring that the equipment be designed:

- To meet the needs of the user.
- In accordance with the codes and standards prescribed for LLNL (e.g., Design Safety Standards, Mechanical Engineering Department, M-012).
- With adequate controls that will reduce operational risks to a minimum (Chapter 2).
- Taking into account the human factors involved when the equipment is operated.
- To facilitate maintenance.

If significant hazards are associated with the use of the equipment, the designer may need to prepare a Safety Note (Section 6.21). Positive control points for equipment power sources must be adequately identified to make emergency shutdown and maintenance procedures easier.

6.21 Safety Notes

A Safety Note is a management-approved document describing the anticipated hazards associated with a piece of equipment. It informs the equipment user of:

- Design parameters to be used.
- Testing and inspection procedures to be conducted.
- Additional information necessary for proper identification, operation, and maintenance of the equipment.

A Safety Note shall be prepared if a significant hazard is associated with a piece of equipment and if the design does not conform to a prescribed standard or management-approved specification. If there is a deviation from a prescribed standard, a variance will be required (Section 2.07). Management may define additional conditions that require a Safety Note.

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A Safety Note should be prepared on Engineering Note Form LL-398 (or on any suitable document) using the following outline:

- **Equipment Description.** State the intended use, proposed location, assembly drawing number, equipment serial number(s), and the name of the responsible user (if known).
- **Operational Hazards.** List all credible operational hazards (Chapter 2), and clearly explain how the equipment is designed to eliminate or minimize them. For complex equipment, consider also a formal system of evaluating all possible ways the equipment could fail (failure-mode analysis). An organized approach of this type will ensure that all parts of the equipment have been thoroughly examined.
- **Design Calculations.** Include complete, legible calculations, and reference the design file by number and location. Use sketches where practical, and reference all sources.
- **Testing and Labeling Requirements.** List testing requirements and any information that must be entered on any labels that will be attached to the equipment.
- **Associated Procedures.** List all procedures and documents (existing and proposed) related to the design, operation, and maintenance of the equipment.
- **Identification Number.** Obtain a number from the Division or Department office and enter it in the upper right corner of each page of the Safety Note.

Approvals

A Safety Note requires the signature of the originator, the person authorized by the Division to review Safety Notes, and the Division leader.

Distribution and Disposition

The originating organization retains the master copy of the Safety Note for the life of the equipment described. Copies of the Safety Note are distributed to:

- The department head.
- Hazards Control Industrial Safety Group (L-384).
- Each person approving the note.
- The equipment user.
- Other persons concerned.
- Central Library file.

Safety Notes can be destroyed when the equipment is no longer serviceable or is disposed of. However, Safety Notes that cover equipment involved in

an incident or accident must not be destroyed until permission to do so is given by the team performing the incident analysis.

Revisions

Safety Notes must be revised whenever they do not accurately describe the equipment. When revising the original master, provide a copy marked "Being revised by (name) (date)" for retention in the permanent files until it is replaced with the revised master. On the revised master, use the number and date of the original Safety Note, but identify each revision by a letter (A, B, etc.) and the date (e.g., Revision A, November 1, 1979). Have the revision approved (signed or initialed) by the same individuals (or their alternates) who approved the original note, and repeat the initial distribution. Identify all revised sentences with the revision letter circled and placed in the right margin (e.g., A).

6.22 Barriers

Barriers required in equipment or facility design, along with necessary warning signs and alarms and with associated locks and interlocks, shall satisfy the requirements set forth in Chapter 11 of this *Manual.*

6.23 Barricades

Barricades required during equipment fabrication or facility construction, along with necessary warning signs and alarms, shall satisfy the requirements set forth in Chapter 11 of this *Manual.*

6.26 Equipment for Use with Explosives

When designing equipment for use with explosives, take special precautions to eliminate the transfer of unwanted energy by the equipment to the explosive, possibly causing a detonation. As a second consideration, see that personnel in the immediate area are given adequate protection from the hazards involved. The following general guidelines apply to all equipment used in explosives work areas:

- As far as possible, design equipment to eliminate cracks, holes, threaded parts, or other places where explosives might accumulate. Avoid the use of pinch-points, or rolling and sliding parts.
- Install redundant, over-temperature safety controls in all thermal test equipment (electrical ovens, thermal chambers, etc.) to prevent thermal runaway. These safety controls shall be independent of the primary temperature-control device, and shall control an independent electrical disconnect between the oven and the power source. They shall also have a manual reset. Steam ovens shall be temperature-limited and controlled with a pressure-relief valve in the steam-supply line.
- Design firing chambers or shot tanks to assure containment. Prepare and submit for approval a Safety Note (Section 6.21) specifying the maximum weight of explosives allowed in the chamber and any other restrictions. Test the chamber by exploding a charge that will produce a pressure 1.25 times the pressure produced by the maximum explosive weight permitted (a 1.25-factor overtest). Periodically evaluate firing chambers using nondestructive testing methods (such as magnaflux or x ray). These tests must be performed throughout the working life of the chamber, the test frequency being based on the number and size of shots fired in the chamber.
- Install appropriate in-line filters in vacuum systems to prevent explosives contamination from entering the vacuum pumps.
- Design all equipment used for remote operations so that their controls are located in an area offering blast and fragment protection to the operator. Interlocks and key-controlled power sources shall be incorporated into the equipment-control chain.
- Provide barricades or operator-protective shields for those remote operations where explosives are tested at an unsafe distance. All new shield designs shall be documented in a Safety Note that specifies proof-testing.
- Electrical equipment (permanent and portable) shall meet the requirements of the NEC (NFPA 70) unless a hazard analysis has been accomplished in accordance with the *DOE Explosives Safety Manual* (Chapter II, Section 8) and the analysis independently reviewed.